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PLANNING CONSIDERATIONS IN THE USE OF SEWAGE LAGOONS

A THESIS

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PLANNING CONSIDERATIONS IN THE

USE OF SEWAGE LAGOONS

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PREFACE

This work is directed to the Planning Commission. No attempt has been made to have this thesis present the technical knowledge necessary in constructing and operating sewage lagoons. The author's background and training do not qualify him for this purpose. Rather, this study represents an effort to provide a general understanding of the sewage lagoon and to indicate the planning considerations involved in its use and placement.

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CHAPTER I

INTRODUCTION

The treatment of sewage is one of the vital services a city must perform. It is as important as providing pure drinking water, but unfortunately many cities have either neglected or been unable to perform this service. The neglect of this responsibility has been largely by small communities that were unable to obtain an efficient, inexpensive sewage-treatment device that could be used on a permanent basis. The inability to meet this responsibility has been caused, in part, by the great increase in suburban development experienced during the past decade with the accompanying increases in cost of sewerage service. This increase has created a demand for an economical and efficient method of sewage treatment that can be used as a temporary facility.

Because many cities have not been able to provide proper sewage-treatment facilities as the need arises, the installation of less effective plants has taken place. Individual septic tanks are often used to meet the suburban demand for sewage disposal, and outdoor privies are still to be found in many small communities. A more recent innovation in sewerage works, the "package plant," has found application in some larger subdivisions. It is a pre-fabricated, small-scale version of a conventional treatment plant.

The use in urban areas of outdoor privies, individual septic tanks and community-type sewage disposal plants such as package plants are only stop-gap measures. Concerted efforts are required of municipalities to insure that these stop-gap measures do not become permanent facilities. In pursuing this objective, the sewage lagoon can prove to be a valuable tool for the rational and economical expansion of municipal sewerage systems. Furthermore, the lagoon can meet the requirements of smaller communities for an efficient and inexpensive treatment plant.

The sewage lagoon,* itself, is an earthern basin which provides a high degree of sewage treatment. The basin is formed by surrounding a leveled area with highly compacted earthen dikes. The entire structure is constructed according to accepted standards (discussed in Chapter IV) to insure that it will function properly. This basin contains the liquid content into which raw sewage is deposited. Within this simplified structure complete treatment of raw sewage is achieved through biological processes.

Growing acceptance of sewage lagoons.--The lagoon method of providing sewage treatment has been the subject of recent widespread interest because of its simplicity and economy. Its areas of application have been so diverse that now lagoons are found on farms and in metropolitan areas, from within the Arctic Circle to the Gulf of Mexico.

The first application of the lagoon method of sewage treatment was reported in 1901 in San Antonio, Texas. This first installation, with one in California and another in North Dakota, are the oldest lagoons in the country. However, they were not designed as lagoons and the sewage treatment that resulted was accidental. For example, the lagoon in Fressenden, North Dakota, was originally a slough. After constructing sewers, the town could not afford a treatment plant, therefore the sewage was deposited in the slough as a necessary expedient. The purification that

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*The sewage lagoon is also called waste stabilization pond, oxidation pond, stabilization basin, and raw sewage lagoon.

took place remained a mystery until, years later, the lagoon was studied to determine the nature of the process.

The first designed lagoon was constructed in Maddox, North Dakota, in 1949. Since that time the interest in, and construction of, lagoons has been phenomenal. The 1957 Inventory of Municipal and Industrial Wastes Facilities, conducted by the United States Public Health Service, revealed that lagoons are being used as the principal treatment device in 430 plants serving 760,000 people (1).

The Water Pollution Control Act of 1956 (P. L. 660) allows construction grants for 30 per cent of the construction costs of sewage-treatment plants with a maximum allocation of $250,000. Cities of any size are eligible for this aid. The total allocation of Congress is apportioned to the various states according to need. Each state administers the distribution of these funds through the state health department or a similar agency. Many sewage lagoons have been constructed under this program. In fact, within four years, this aid has almost doubled the number of lagoons in the country. As of May 31, 1960, 418 raw-sewage lagoons has been approved for construction under this program. Many other lagoons have been constructed without this aid and now lagoons are being used in 39 states (2). It would be safe to assume that there are now over 1,000 lagoons in operation in the United States. The development of the lagoon method of sewage treatment is increasing and its application expanding.

<u>Purpose and procedure</u>.--This study is concerned with investigating the unique features of sewage lagoons to determine how best they may be applied to an urban environment. Of prime importance is the use of lagoons to implement the orderly growth of a municipal sewerage system.

This is a major problem that confronts our cities today as they struggle to meet the increasing demands for sewerage service.

Chapter II explains the biological operation of the sewage lagoon. The close relationship of the lagoon's biological processes to the natural self-purification of streams is explained.

Chapter III discusses the benefits and limitations of the sewage lagoons. This chapter establishes the fact that the advantages of using lagoons far outweigh their limitations.

Chapter IV discusses some of the site requirements, construction standards, and operational problems associated with lagoons. While no effort is made to prescribe definite standards or practices, the chapter provides a basic explanation of these aspects of the sewage lagoon.

Chapter V explains how a lagoon may be adapted to various situations in an urban environment. Examples are given to demonstrate the flexibility that may be obtained in municipal sewerage systems through the use of lagoons.

Chapter VI is a summary of the thesis. It defines the sewage lagoon, outlines its most outstanding characteristics, and mentions its various applications.

CHAPTER II

HOW THE SEWAGE LAGOON FUNCTIONS

All sewage-treatment processes attempt to emulate nature's own process for the purification of wastes. Although man's efforts have resulted in many diverse and complicated systems, the fundamental laws of nature still constitute the guides for their design and construction. These fundamental guidelines are: the dilution of the wastes, the separation of liquids and solids, and the purification of each through different mediums.

Natural self-purification.--Natural self-purification is the process that is carried out whenever wastes enter a stream, river, or other water body. The water dilutes the incoming wastes and allows the solids to settle to the bottom. Anaerobic bacteria (bacteria not dependent on free oxygen) attack the settled solids and decompose them; aerobic bacteria (bacteria dependent on free oxygen) survive on the water body's oxygen supply and break down the liquid wastes. The critical element in the process is oxygen. When a water body becomes depleted of oxygen, it is incapable of performing the treatment process.

Streams and large bodies of water obtain their oxygen by absorption. This is a highly variable means of securing oxygen, depending on the amount of agitation and on the temperature. The lagoon relies for its oxygen on algae, a form of life that liberates oxygen in the process of photosynthesis. Algae, while also affected by temperature, can produce much more oxygen per given volume of water than a stream is able to secure through absorption.

The purification process of lagoons.--The sewage lagoon operates through biological, physical, and chemical processes in a manner similar to the natural process. The prominent factor in the lagoon process are: algae, bacteria, and sunlight. These factors are shown schematically in Figure 1.

Sewage, on the whole, is devoid of oxygen. This imbalance in its chemical composition creates a demand for oxygen by bacteria that must be satisfied if the sewage is to be purified. This demand for oxygen is called its Biochemical Oxygen Demand. In lagoons, algae are the agents which supply the oxygen to satisfy the BOD. The use of algae as the oxygen producer is a vital and distinguishing characteristic of the sewage-lagoon method of treatment.

As sewage enters a lagoon it disperses throughout the area and the solids settle to the bottom. Algae and aerobic bacteria operate in its upper strata. The anaerobic bacteria attack the sewage solids and decompose them. Through this action chemical nutrients are released. These nutrients (carbon dioxide, nitrogen, and ammonia) are the main food source for algae.

The algae absorb the nutrients resulting from the anaerobic action as well as those contained in the liquid wastes and with the aid of sunlight and oxygen carry out the biological process of photosynthesis. One product of the photosynthetic process is oxygen. This oxygen is then used to satisfy the BOD of the sewage and the wastes are rendered unobjectionable. This process is essentially self-sufficient and under normal conditions can operate continuously without mechanical aids or human manipu-

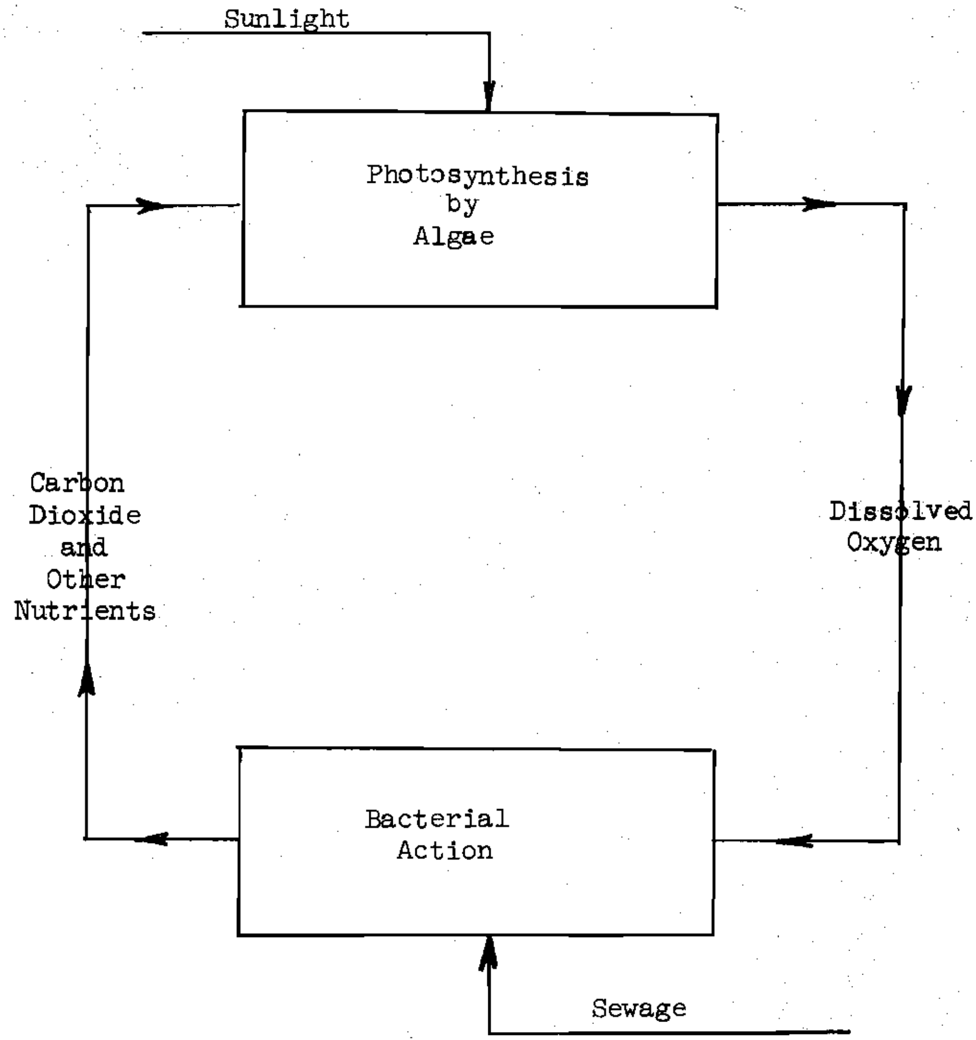

Figure 1. Purification Cycle of Sewage Lagoons (3).

lations. This, fundamentally, is the purification process which occurs in lagoons and constitutes their unique method of sewage treatment.

The relationship between natural self-purification and the sewage-lagoon method of treatment can be readily understood when their common features are compared. Both systems have a body of water in which the wastes are diluted; both systems allow solids to settle to the bottom; and both allow aerobic and anaerobic bacteria to purify the wastes without mechanical or chemical aids. The only point of major deviation is the oxygen source.

CHAPTER III

BENEFITS AND LIMITATIONS OF THE SEWAGE LAGOON

The benefits to be derived from a lagoon are extensive. If the local environment is conducive to the construction of a lagoon, the city can realize many benefits through the exploitation of one or another of its many applications.

Benefits of the Sewage Lagoon

To adequately judge the benefits that can be derived from using a sewage lagoon, the qualities that make up its versatility should be explored. Its adaptability and low cost make it ideally suited for use as a sewage-disposal facility in selected portions of large cities or in small communities.

Adaptability

The lagoon can be used as either a permanent or temporary facility to provide complete, or secondary, treatment. In serving in any of these capacities, the lagoon performs at a high level of efficiency.

Permanent facility.--As a permanent facility, the lagoon can be used in a variety of situations to implement the orderly growth of the sewerage system. Many small communities do not have treatment plants or the ones they possess are antiquated and inefficient. In this case, the lagoon may be used as the sole treatment device. It will prove to be an economical and highly efficient installation. It can also be used as a treatment facility for isolated developments or for drainage basins that are particularly difficult to reach with existing facilities. For these areas the lagoon may be the only treatment device that could possibly be considered financially. In any of these capacities it can perform indefinitely because within the treatment process the solids are almost completely destroyed; therefore, the capacity of the pond can not be reduced by a sludge build-up.

Temporary facility.--Since the lagoon is an inexpensive facility, it is especially adapted to temporary use. It also has the advantage of being easily abandoned or disassembled without incurring a financial loss in unamortized equipment. These are benefits that few other treatment plants can claim.

The best temporary use of the lagoon is as a device to meet increasing demands for sewerage service. It is commonly used to provide sewage treatment for a new subdivision until municipal sewers can be extended to serve the area. Another use is to accommodate new growth areas while the existing treatment plant is being enlarged to accept this increased flow.

Complete treatment.--The lagoon ordinarily provides complete treatment, i.e., treatment of both liquids and solids. This is not necessarily the case with conventional plants. They can offer either primary or both primary and secondary treatment. Primary treatment consists of treating the sewage solids and floating material and discharging the liquid wastes into a stream untreated. Secondary treatment is a continuation of the primary process in which the liquid wastes are treated before discharge. For a conventional plant to provide secondary treatment in addition to primary treatment more equipment must be secured. The sewage lagoon, however, offers both primary and secondary treatment within one simple unit. In 1957, 430 of the 631 lagoons operating in this country were used to provide complete treatment (4).

Secondary treatment.--The lagoon has also been used solely as a secondary treatment device in place of trickling filters. Solids are removed through conventional means and the liquid wastes are treated in lagoons. This application has been most extensive in the Southwest where water is a precious commodity and wastes must be treated to an exceptionally high degree before discharge into a watercourse. In a few instances where the highest degree of purification possible was desired, the lagoon was used as a tertiary treatment device to "polish" the effluent from conventional secondary plants.

Financial Attractiveness

The sewage lagoon represents a most important break-through in the cost of providing sewage treatment. It has put sewage treatment within the financial reach of small municipalities and of subdivision developers alike. Initial construction costs are low and operational costs are insignificant.

The sewage lagoon is competitive with numerous types of treatment facilities on a cost basis. Most frequently the cost of lagoons is compared with the cost of conventional plants in small communities and with the cost of package plants or individual septic tanks for suburban development. This section will compare the fixed and operational cost items of lagoons with those of conventional plants, package plants, and septic tanks.

Sewage lagoon costs.--Four items comprise the bulk of sewage-lagoon-construction costs: (1) the acquisition of the site; (2) earth-moving for dike construction; (3) inlet and outlet structures and their appurtenances; and (4) fencing. Each of these cost items can vary substantially according to the locality, but generally land is the most costly item.

A lagoon requires the services of a part-time, unskilled worker. The ability of the lagoon to accomplish its treatment process unaided means that this person will be primarily concerned with maintenance procedures while keeping a watchful eye on the lagoon to detect any problems that might arise. If problems should arise, most can be corrected through simple procedures.

Conventional plant costs.--The conventional plant is an arrangement of mechanical equipment and devices. Each of these mechanical components represents a fixed cost and when added to the land requirement, the total cost becomes substantial. The lagoon, on the other hand, is primarily an investment in land and generally does not require mechanical aids.

The operational costs of conventional plants are much greater than those of lagoons. Fully trained operators must be available at all times to insure proper operation and also to correct any mechanical breakdowns. The lagoon requires only an unskilled person on a part-time basis.

If a conventional plant is to be truly comparable to a lagoon, it must provide secondary treatment. However, a conventional plant providing complete treatment has been found to have construction and operational costs "... nearly twice as great as costs for plants providing primary treatment alone" (5). It is this cost factor of conventional plants providing complete treatment that has made them impractical for all but large, developed service areas.

Package plant costs.--The package plant is the most nearly comparable treatment facility to the lagoon. The situations in which it is used and its treatment capacity are frequently similar. However, it is a relatively permanent structure, which means that its fixed costs must be amortized during its period of operation. This makes it less desirable as a temporary facility than the lagoon.

The initial cost of a package plant is also frequently greater than that of a lagoon. "Depending on the value of the land, the USPHS estimates that a pond costs only 25 to 40 per cent as much as the cheapest mechanized plant of comparable capacity" (6). The package plant also has the disadvantage of requiring a skilled operator, thereby increasing its operational costs over those of a lagoon.

Septic tank costs.--The installation of a lagoon can actually be less expensive than the aggregate cost of installing septic tanks in a new development. This determination of relative costs depends largely on the size of the development, the price of the land, and the cost of septic tanks in a given locality. Larger developments or those anticipating future expansion should consider the lagoon as a community sewerage facility, for as the number of houses increases the dollar advantage of the lagoon system will become greater. This is because of the relatively constant per-dwelling-unit cost of septic tanks and the decreasing per-dwelling-unit cost of lagoons. In the Midwest, the break-even point of the two systems is generally stated as 100 houses.

It is difficult to compare the operational costs of sewage lagoons and septic tanks. However, it is known that septic tanks periodically must be cleaned and that occasionally a tile field must be torn up and replaced. If the operational costs of all septic tanks within a given service area were totaled, it would seem likely that the sum would equal, if not greatly exceed, the operational costs of the sewage lagoon.

Limitations of the Sewage Lagoon

The sewage lagoon has great versatility, yet there are certain limitations to its use. Its greatest limitation is its large land requirement. This requirement can effectively eliminate a lagoon in high-density areas if sufficient land is not readily available nearby. There are also practical limitations to the maximum and minimum size of a lagoon. Another limitation is the condition of soils in a particular locality.

Large Land Requirement

The land area required for a lagoon installation is a serious limiting factor if the lagoon is to be placed in an urban area. The lagoon site is usually measured in acres. This means that the site must be spacious. Therefore, the lagoon can be used only in areas where sufficient land can be obtained near the service area. For small communities this is usually not a problem, but in metropolitan areas this land requirement relegates the lagoon to a suburban location. Even in a suburban area it might be difficult to find a large area that could be used as a lagoon site.

Maximum Size

The maximum possible size of a lagoon has not been determined.

There is however, a practical limitation to its maximum size. With a large lagoon a substantial surface area is exposed to the wind. On a windy day the wave action may become excessive and cause rapid deterioration of the dikes. Therefore, it is highly recommended that large lagoons be developed as a group of small interconnected cells. With a multicell facility the problem of erosion is curtailed. A large lagoon constructed in a natural depression of the earth's surface so that dikes are not required will not experience the erosion problems of a large lagoon surrounded by man-made dikes. In this respect, the size of the natural depression will be the only limiting factor on the size of the lagoon.

Minimum Size

In exceptionally small lagoons there will be difficulties in maintaining a biological balance. A subdivision of 74 houses near Milwaukee, Wisconsin, is served by a lagoon of 1/3 acre and is performing well (7). However, this lagoon has mechanical aeration. It is the opinion of Mr. H. C. Duke, sanitary engineer of the Fulton County (Atlanta) Health Department, that a lagoon of less than one acre will require such careful operation to maintain a biological balance that its practicality will be lost (8). In lagoons of less than one acre that are not mechanically aided, the daily fluctuation of inflow will greatly affect the ability of the lagoon to sustain a constant level of efficiency. For this reason, small lagoons, unaided by mechanical devices, should be not less than one acre in area.

Soil Conditions

The type of soils existing in an area will, to a large extent, determine the feasibility of the lagoon method of sewage treatment. Some areas of the country have soils that are not suitable for the installation of a lagoon, primarily because of the soil's inability to retain the liquid contents. Loose or fissured soils are the type which offer the greatest difficulty; impervious soils are the most desirable.

Porous soils, however, have been treated to make them suitable for a lagoon. Such materials as gunite, soil cement, asphalt, and some plastics have been used with success, but the use of these materials increases the cost of the facility. This increased cost might be sufficient to destroy the economic advantage of the lagoon and makes its use infeasible.

Summary

The benefits of lagoons are much more extensive than their limitations. If the lagoon is at all feasible, it can be used as an interim or permanent facility to provide complete or secondary treatment. The low construction and operational costs of lagoons are financially attractive. In any favorable locality these benefits can be enjoyed by a community through an intelligent application of the facility.

The limitations of sewage lagoons are important because they can materially affect the practicality of a lagoon installation at a particular location. In urban areas it might prove difficult to secure the large land areas required to accommodate a lagoon. Operational problems might arise if the facility is not greater than one acre in area. Further difficulties can result from lagoons located in areas with unfavorable soils or from exceptionally large lagoons. However, in the majority of cases, these limitations are easily surmounted.

CHAPTER IV

SITE REQUIREMENTS, CONSTRUCTION STANDARDS, AND OPERATIONAL PROBLEMS

Basic standards and practices which influence the location, construction, and operation of lagoons have gradually been developed. They have been compiled largely from the empirical data on existing facilities. An adherence to these standards and practices will assure the continued high level of performance expected of lagoons.

Proper location and construction of a lagoon will eliminate many operational difficulties. For this reason it is important that the site requirements and construction standards be observed. However, it is important also to be aware of the common operational problems that can arise in order that they may be corrected quickly and easily. The most common operational problems, therefore, are discussed and the prescribed corrective measures are explained.

Site Requirements

The sewage lagoon must be properly located if it is to perform satisfactorily. Most failures of lagoons have resulted from inadequate preliminary investigation of the proposed site. Care should be taken to adhere to the following fundamental requirements for a lagoon site.

Location with relation to residences.--A sewage lagoon, being a sanitary-treatment facility, should generally observe the locational requirements that are commonly applied to conventional sewage-treatment plants. However, there is always the possibility of a plant failure and consequently the creation of nuisance problems. For this reason the lagoon should have a protective buffer area of undeveloped land so that nuisance complaints will be minimized.

Standards established by some state health departments recommend that a lagoon be placed at least one-quarter mile away from the nearest residence. This means that approximately forty acres of land will be required to separate the plant from nearby homes. Fortunately, USPHS engineers have acknowledged that this standard need not be universally applied. "In areas where aerobic conditions can be maintained throughout the year, the distances may possibly be reduced" (9).

Lagoons located much closer to habitations have been reported. "USPHS biologist, Dr. Joseph Neal, reports numerous instances in which ponds (lagoons) have been built within 100 yards of a home, church, school, office building, factory, drive-in theater, or trailer camp with no problem of either odor or pollution" (10). A lagoon located in Milwaukee, Wisconsin is described as being "... located 300 feet from the nearest residence" (11). In a 12-state survey conducted by the National Association of Home Builders Research Institute, it was "... indicated that the average distance of the treatment facility from the nearest home was between 400 and 500 feet" (12). There would appear to be sufficient evidence to indicate that a lagoon, if properly designed and constructed, can be situated in residential areas with a buffer strip of only a few hundred feet.

There is also a problem of public relations to be considered when selecting a location for a lagoon. A sewage-treatment plant is not genererally considered a desirable neighbor regardless of the type plant it happens to be. It is therefore suggested that the installation be made either attractive or inconspicuous. A lagoon has a definite advantage over conventional-treatment plants because of its potential attractiveness. This potential can be developed with proper landscaping since it is essentially a small body of water. If this policy is not thought to be satisfactory, the lagoon can be situated where its presence will not be observed.

Open area.--The ability of the wind to agitate the surface of the water plays an important part in the normal operation of a lagoon. Wave action is beneficial for dispersing the raw sewage throughout the entire liquid area. For this reason an unobstructed wind sweep is desirable and should be provided.

Adjacent to a stream.--A continuously flowing stream is a necessary adjunct for most lagoons. In those areas of the country where annual evaporation exceeds annual sewage input, the contents of a lagoon may be dispersed through solar evaporation. But, this process is not sufficient for most areas since sewage input and rainfall will generally exceed evaporation. Therefore, a nearby stream is needed to receive the discharge from the lagoon. It is usually desirable to have the structure bordering a stream so that the cost of constructing an outfall sewer can be reduced.

Soil porosity.--Most failures of lagoons have been the result of improper location on soils which are not suitable for lagoon construction. Lagoons that have been constructed over gravel beds, fissured limestone, or in sandy soils have produced unfavorable results because seepage could not be controlled.

Seepage is a danger to be considered in planning for lagoons. Porous soils which allow the contents of the lagoon to seep into the surrounding area can create public-health problems. The underground water may become polluted by lagoon seepage. If seepage is prolific, difficulty will be experienced in maintaining a constant water level in the pond and the operating efficiency will thereby be diminished. The dikes which hold the liquid contents of the lagoon will also lack the necessary structural strength if constructed of such soils.

Construction Standards

The lagoon structure is essentially an earthen basin designed and constructed to hold a given volume of liquid at a depth ranging from two-and-one-half to five feet. The shape should be uniform with no coves or peninsulas. For the efficient operation of the purification process, control must be exercised over the liquid depth to prevent aquatic weed growth and to maintain a balanced biological process.

The entire body of water is surrounded by compacted or specially treated dikes having controlled inside and outside slopes. (See Figure 2.) These specified slopes are necessary to prevent erosion and to provide a solid structure. Grass is planted on the dikes to hold the soil and frequently rip-rap is placed at the water-line as a further erosion-control measure. Often the dikes are very highly compacted to allow maintenance vehicles to travel on them.

Sewage enters the lagoon by way of an inlet pipe that discharges it at the center of the pond. The central discharge of wastes is required to insure an even distribution over the entire liquid area. A

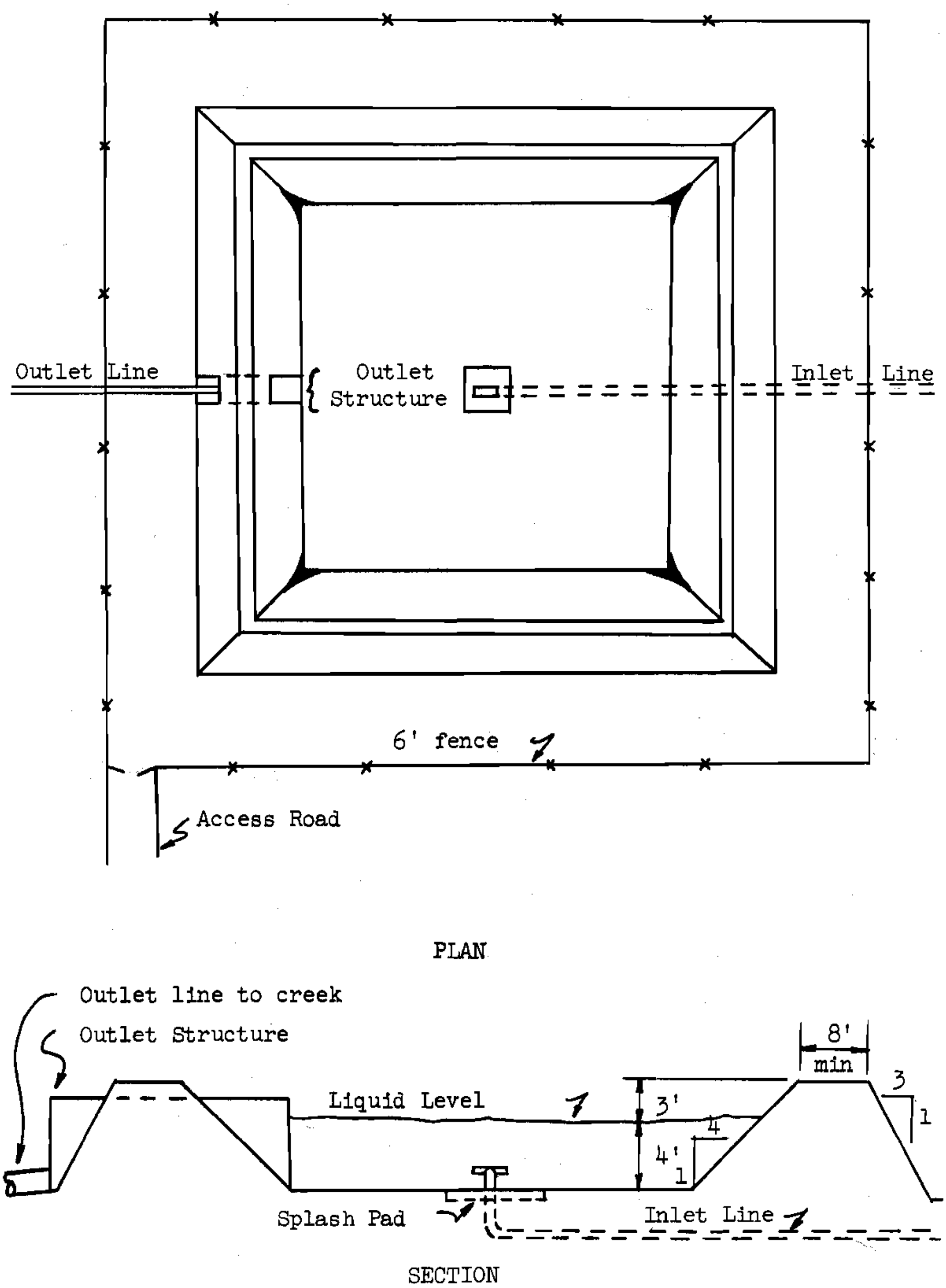

Figure 2. Diagram of a Sewage Lagoon.

concrete splash pad should be provided under the mouth of this pipe to prevent bottom scouring.

The outlet structure is placed at a point sufficiently distant from the inlet to prevent the quick flow of raw sewage directly from the inlet pipe to the outlet structure without sufficient treatment. Evaporation, droughts, and rainstorms all affect the level of the pond. Therefore, controlled points of withdrawal should be placed at varying depths in the outlet structure to allow surface and subsurface withdrawals.

The lagoon must be completely fenced. The fencing need be only stock-tight in rural areas, but a higher degree of protection is needed in areas of dense population. This is a necessary safety precaution to prevent curious children or animals from entering the lagoon site.

Operational Problems

The operational requirements are concerned with the correction of recurring problems that can cause malfunctions and malodorous conditions. The most common operational problems are: winter-spring transition; algae overpopulation; excessive loadings; toxic loadings; nuisance control; and dike protection. To insure that the lagoon functions at a satisfactory level of efficiency, these recurring problems should be anticipated and, if they occur, corrected before they can substantially alter the biological process.

Winter-spring transition.--The winter-spring, anaerobic-aerobic transition period experienced by lagoons located in the northern climates is the most critical phase of the yearly operation. While the pond is under a cover of ice, the treatment process functions anaerobically, a process that produces odors. However, with the advent of spring and thawing ice, the process converts to an aerobic system. This conversion might be accomplished in a matter of days or weeks, depending upon the temperature and other factors. It has been during this transition period that the greatest problems have been reported.

Careful operation of the lagoon during this stage is essential if the transition is to be accomplished quickly and as free from malodorous conditions as possible. The common procedure is to lower the depth of the pond to approximately two feet as the thaw begins. When the ice cover is melted, the lowered depth will accelerate the growth of algae since sunlight can penetrate the entire liquid depth. When the algae growth is well underway, the depth of the lagoon is again raised to its normal operating level.

Algae overpopulation.--Some lagoons have experienced the problem of algae overpopulation. Its most common form is a thick blanket of living or dead algae cells covering the surface of the pond and excluding sunlight. This accumulation of cells can result from the pond's experiencing either a slightly toxic waste that kills a good portion of the algae population or a prolonged period of still winds which allows the cells to mass near the surface. When this happens the efficiency of the lagoon is lowered and malodorous conditions can arise.

At a lagoon installation in Mississippi, algae overpopulation occurred because of a prolonged period of still winds. The operator placed a small skiff with an outboard motor in the lagoon and rode around the pond to break up the blanket of algae. This simple procedure proved successful (13). The most common procedure, however, is to remove a portion of the algae through surface-water withdrawals.

Excessive loadings.--Lagoons are capable of sustaining short periods of excessive non-toxic loadings, commonly called shock loads. Such instances are unpredictable and should be guarded against. The lagoon is better able to sustain a shock load during the daylight hours of the summer months because this is the period when it is operating at maximum efficiency. Prolonged overloaded conditions, however, will cause the biological system to become imbalanced and fail.

To combat this problem, a high degree of co-operation with commercial and industrial establishments is needed. If a huge volume of wastes were to be discharged from a plant, the city might require advance notice and schedule the discharge during the off-peak hours of the lagoon's operation. With co-operation, this procedure can be successful.

Toxic loadings.--Toxic materials such as oils, cyanide compounds, and certain chemicals and minerals, are the greatest danger to any sewage-treatment operation. A load of toxic materials will cause the biological system of the lagoon to completely malfunction. Once this happens, the only alternative is to drain the pond and cultivate as quickly as possible a new crop of algae.

Common protective practice is to make chemical analyses of the wastes of large contributors such as industries. If toxic materials are found, the contributor should be required to pre-treat his wastes to remove the toxic material before discharging them into the municipal system. This investigation should be undertaken prior to the construction of a lagoon and be continued for all new commercial and industrial establishments that are connected to the municipal system.

Nuisance control.--If a lagoon is properly designed and not overloaded, it should function without any problems of odor or of mosquito propagation. Instances where these problems have arisen are few and have generally resulted from poor operational practices. In a large lagoon the odor nuisance potential is greatly magnified because of the increased surface area. With a multi-cell facility it is possible to isolate nuisance problems to a single cell. Introducing sodium nitrate to the contents of a malfunctioning lagoon will supply the oxygen needed to reestablish a proper biological balance and cause the odor production to cease.

Mosquito propagation is a problem that should arise only through faulty design or operation. Mosquito larvae thrive in still water; therefore, proper operational procedures should remove all shoreline or overhanging growth that might act as a shield against the normal agitation of the lagoon's surface by the wind. If further protection is desired, minnows (genus: Gambusia) may be placed in the pond to eat the mosquito larvae or a commercial larvicide can be used.

Dike protection.--The major structural element of the lagoon is the dike which surrounds the pond and holds its liquid content. The dike must be protected against burrowing animals and deep-rooted weeds. Periodic inspection of the installation and the removal of weeds will suffice for weed control, but burrowing animals must be discovered quickly and removed. This can usually be done by trapping the animals.

Proper site selection and good construction can greatly reduce the operational problems of a lagoon. Most of the reported lagoon failures have resulted from not observing these two points. However, the operator of a lagoon should be cognizant of the common operational problems associated with lagoons and the usual procedures for combating them. With a properly located and constructed lagoon and an operator who is aware of operational problems and procedures, the lagoon should prove to be a highly successful facility.

CHAPTER V

PRACTICAL APPLICATIONS OF SEWAGE LAGOONS

The sewage lagoon has been adapted to many different situations within and around urban areas. These diverse situations in which the lagoon has been applied emphasize the adaptability of the lagoon as a treatment facility. There are appropriate applications, however, which, to the author's knowledge, have not yet been attempted. This chapter will recount some of the more successful uses of the lagoon and suggest where its applications may be extended. In general, these areas of application fall into three broad categories: small communities, metropolitan areas, and isolated developments.

Small Communities

Sewage lagoons have had their widest application as permanent facilities for communities of less than 5,000 population. For communities of this size, the cost of conventional-treatment plants if often an insurmountable obstacle, even though the desire exists to correct unsanitary conditions. The inexpensive sewage lagoon method of sewage treatment has offered a new alternative for providing this service.

The predominant use of this method of sewage treatment by small communities is demonstrated by an analysis of the 1957 Inventory of Municipal and Industrial Wastes Facilities. Cities of less than 5,000 population have constructed approximately 95 per cent of the 399 lagoons used as the principal treatment device and approximately 85 per cent of the 545 lagoons used in conjunction with other treatment devices.

Table 1. The Use of Lagoons by Cities, 1957 (14).

Population of Cities	Component Device: No. of Plants	Component Device: Est. Pop. Served	Principal Device: No. of Plants	Principal Device: Est. Pop Served
Under 500	114	38,500	101	34,413
500 to 1,000	127	87,746	101	71,926
1,000 to 5,000	304	582,878	197	348,111
5,000 to 10,000	52	326,791	23	131,991
10,000 to 25,000	23	322,027	4	48,000
25,000 to 50,000	4	178,500	2	76,500
50,000 to 100,000	2	170,000	---	-------
over 100,000	5	656,400	2	49,000

The lagoon can also be used to stage the construction of a conventional-treatment plant. The growth of the sewerage system will determine the rapidity with which the staging process will advance. However, since sewage treatment is provided in all stages, the process need not reach its final stage to be effective. If the community's rate of growth is curtailed the staging process can be altered accordingly, without detriment to the community or the sewerage system. If such a program is to be undertaken, a site should be acquired that will make allowance for future expansion.

The staging process would be initiated with a single lagoon. As development increases, the lagoon should be expanded to a multi-cell facility. However, when land availability precludes continued expansion of the lagoon system, conventional treatment facilities should be phased into the operation. Eventually, the lagoons will be abandoned and the site used for the more compact mechanical-treatment plant.

The low construction and operational-costs of the lagoon, as well as its ability to aid the rational expansion of treatment facilities has, for the first time, enabled many small communities to provide their citizens with good sanitary service. Mr. J. E. Johnston, Director of Sanitary Engineering of the Mississippi State Board of Health has said:

> Since the introduction of lagoons in Mississippi, we feel that adequate sewage treatment is well within the financial means of any community. Their use has opened the way for communities to clean up their environments -- a thing that many were not financially able to do before (15).

Metropolitan Areas

Until recently, sewage-treatment facilities were designed for either urban or rural use. With the advent of urban sprawl, a type of development arose that was neither fully urban nor rural. Because of this development, a demand was created for an intermediate sewage-treatment facility that could provide good service until densities approached an urban level. Septic tanks were the immediate answer, but experience has demonstrated that they should be limited to rural use. The ring of suburbs served by septic tanks that surrounds many metropolitan areas has become a substantial barrier to the extension of the metropolitan-sewerage system. Increased expense and public opposition are encountered when a city attempts to incorporate a septic tank area into the metropolitan system.

The lagoon now offers a method of developing a metropolitan-sewerage system in an orderly and efficient manner without the problems inherent in the septic-tank system. When considered as a tool for sewerage-system development, the lagoon can be used as either a permanent or interim facility, according to the demands of the particular situation. Many cities have already realized the potential of the lagoon as a development tool and have made good use of its versatility. Examples of how lagoons can aid the development of sewerage systems in metropolitan areas are given to illustrate their practicality.

Lagoons as a Permanent Facility

Urban centers seldon expand in a uniform pattern. Many obstacles lie in the path of urban growth and cause it to conform to natural limitations. In most cities areas can be found where, because of topographical or other physical barriers, little development has taken place. Such areas are frequently called "dead" land.

To extend existing sewerage facilities into these areas is often impractical and, many times, impossible. In such instances separate facilities must be provided if the area is to develop. By providing water and sewerage service to an undeveloped area, the vital services needed for development are supplied. This has the effect of adding new land to the total supply of land available for construction in the local market.

In providing sewerage service to these areas, lagoons can be used as a permanent treatment facility to supply the necessary sewage treatment. By using this approach, "dead" land can be put to a profitable use with the result that greater tax revenues will be realized and a more economical method of sewerage service is provided.

The Planning Commission should attempt to coordinate the placement of these permanent lagoons with an open-space plan. The lagoon could be constructed in a "free-form" shape and placed in the open area to act as a picturesque, reflecting pond. Access to the lagoon will be prohibited, but the aesthetic value of the open space would be enhanced by exploiting this characteristic of the lagoon.

Lagoons as an Interim Facility

An inexpensive sewage-treatment facility that could be used on a temporary basis has been desired for many years by both municipalities and subdividers. Septic tanks and pumping stations with force mains have been used in an attempt to fill this need, but generally with unfavorable results. Pumping stations are expensive facilities and are also difficult to expand. Septic tanks are actually a poor interim device because of their improper use and the difficulty experienced in subsequently converting the area to the metropolitan system.

The sewage lagoon, however, has been recognized as a promising method of interim treatment. It meets most, if not all, of the following criteria for an interim facility (16):

1. installation costs should be low,
2. it should provide continuous service,
3. it should be either attractive or inconspicuous,
4. odor or other nuisance problems should be minimized, and
5. operational costs should be low.

From the viewpoint of the subdivider, one of the most beneficial aspects of installing lagoons as the interim-treatment facility is its almost 100 per cent salvage value. When the subdivision is joined with the city system, the lagoon site can easily be reclaimed for housing development, often at a greatly appreciated value. This benefit does not exist with other types of community-treatment facilities.

The community system of sewers that is installed to supply a sewage lagoon comprises an asset to the homeowner, his neighborhood, and the city. The original purchasers of homes absorb the cost of sewage-disposal facilities in the price of the house and lot. If individual facilities were provided, such as septic tanks, the homeowner would have to pay again for the same service when the metropolitan system became available. In addition, the cost of installing sewers in a developed area is three to four times as great as in raw land. The homeowner, then realizes substantial savings if his area is originally supplied with a community sewerage system.

The neighborhood and the city also realize a financial benefit when the subdivider originally installs a community sewerage system: the neighborhood through increased property values; the city through a donated system of installed sewers. The incidental benefit of not having to tear up and repair streets also accrues to the city.

Whenever an interim lagoon is planned for a suburban area, the Planning Commission should thoroughly explore the reuse potential of the proposed site. The lagoon site will be an expansive, level area within walking distance of most residences. As residential development proceeds, this site is likely to become surrounded by new subdivisions. Once the lagoon is abandoned, the site could easily be adapted for use as a neighborhood park, or, if the site is large enough, as a possible location for a school. Such planning can result in substantial savings for the community.

Lagoons have been used successfully as interim-treatment facilities in metropolitan areas. The following three examples are all similar in that the lagoon is used as a tool for sewerage system development, but they differ in method.

Chicago Sanitary District.--Recently the northern and western boundaries of the Metropolitan Sanitary District of Greater Chicago were extended to take in a large area of new development. In so doing, the Sanitary District assumed responsibility for the collection and treatment of the additional wastes. However, the existing facilities would have to be extended in order to adequately service the new area. Such a project would be time consuming.

Until existing facilities could be expanded, sewage lagoons were utilized. These lagoons provided treatment for established communities and newly developed housing areas. The lagoons are to be removed as soon as the contributing areas can be connected to the metropolitan system. Similar use of the lagoon is being made in Denver, Pittsburg, and Seattle (17).

Atlanta-Fulton County.--In the metropolitan Atlanta area a program for meeting sewerage-expansion needs has been developed and is being effectively enforced through the cooperation of the Fulton County Health Department, the Atlanta Sewer Department, and the Atlanta-Fulton County Joint Planning Board. A new treatment plant and collection system are under construction to serve a rapidly growing sector of the city. The cooperating agencies have adopted a policy of requiring subdividers to install sewers in all new developments within the watershed so that service can be easily provided once the trunk lines and plant are operating. The choices open to the subdivider are: (1) use septic tanks, but also install "dry" sewers; (2) provide a community treatment facility; or, (3) postpone development until the metropolitan facilities are made available.

Many subdividers have chosen to proceed with development and some have used lagoons as the community-treatment facility. Since the trunk lines are gradually being extended and put into operation, the number of lagoons in operation at any one time has fluctuated, but they average about five. They range in size from one to ten acres, according to the size of the subdivision. The operation and maintenance of these community treatment plants becomes the responsibility of the governmental jurisdiction in which they are located.

Jackson County (Kansas City), Missouri.--Jackson County, Missouri, offers an excellent example of how the sewage lagoon may be used to stage the development of a watershed. This county is absorbing much of the suburban growth of Kansas City. Basically, the program is designed to make sewerage-system development keep pace with subdivision development, an undertaking which has proved almost impossible for many cities.

A master sewerage plan was prepared to show the existing facilities, the route of proposed trunk sewers, and the proposed location of major treatment plants. With this plan serving as a guide, subdividers and local officials are striving to develop an orderly and efficient sewerage system.

Two administrative policies have been instrumental in determining the type of sanitary service provided the urban fringe area. The county zoning ordinance allows a reduction in lot size from 15,000 to 7,500 square feet if a community sewerage system is installed; and secondly, "... the state and local health authorities have strongly discouraged the use of individual septic tank systems in the urban fringe of Kansas City"

(18). Septic tanks, of course, are still being used, but the advantage of building two houses with sewers on the same amount of land as one house with a septic tank has greatly reduced their popularity.

To obtain building permits for a fringe-area development that will use a community treatment facility, the builder and/or developer must first form a sewer district encompassing the entire subdivision. This is done simply by a petition to the county governing body. He must then receive zoning approval for a sewage-lagoon site and construct the treatment facility and its collection system.

The lagoon site must be supplied by the developer. This requirement might be altered if the lagoon were to serve an area greater than the developer's subdivision. If a larger lagoon is needed to "phase-out" a smaller one, the county might construct the facility on a site contributed by the developer. Once the lagoon is phased-out, the site usually reverts to the developer.

With the installation of the lagoon and its collection system, the developer and/or builder can request building permits. However, building permits must be obtained for at least 25 houses and a sum of $5,000 ($200 per house) placed in an escrow fund of the county. For each additional house that he wishes to construct, another $200 must be placed in the escrow fund.

> The funds are controlled by the county to be used in the construction of intercepting sewers and permanent treatment plants that will eventually eliminate use of the temporary stabilization basins. These funds can also be used by the county to construct larger sewers down the tributary watershed so that eventually sewage from several subdivisions may discharge into a larger basin.... which, under a master plan for construction of permanent treatment facilities, will eventually be eliminated (19).

Jackson County has realized many benefits from its sewerage-development program. Most of the financing has been shifted from the county to the developer, but control over the system is maintained by the county governing body. The program is, in effect, a pay-as-you-go system with the incoming residents paying for the services they receive.

The individual neighborhoods are receiving the benefits of superior sanitary service from a complete system of sewers and a treatment plant that can discharge an effluent of highest quality. Streams adjoining the new developments are kept free from pollution, thereby making them safer for the play of youngsters.

The greatest advantage, however, is that the subdivision is serviced with a completely adequate treatment facility when it is originally developed. It can be tied in with the metropolitan system easily and economically. The homeowner is thereby relieved of the cost of paying twice for the same service.

The entire county is receiving the benefits of a sanitary sewerage system that is keeping pace with development and one that is meeting the needs as they arise on a firm financial basis. The added safety measure of one central agency responsible for satisfactory operation and maintenance is also provided the citizens. This program of development has given the citizens quality sanitary service without placing an undue financial burden upon them.

Isolated Developments

There are many types of developments which characteristically remain isolated from urban areas and can be considered as communities within themselves. Lakeshore colonies or resorts, highway-oriented developments, and various community-type developments are all examples of independent groupings of people and structures. They represent an aggregation of people and therefore a need for sewage treatment. The sewage lagoon can easily be adapted to satisfy this need.

Isolated developments will be serviced by facilities that are individually installed. While the facility might not affect the municipal sewerage system, its design and construction should be controlled for sanitary reasons. County health officers can review plans and inspect construction so that the facility will conform to accepted standards.

Lakeshore Developments

The water-oriented recreational trend this country is experiencing has brought an accompanying growth in lakeside resorts and colonies. These developments are all dependent upon a body of water so it is a matter of prime importance to assure that this water does not become polluted through inadequate sanitary facilities. The close proximity of bathing areas often prohibits a subsurface disposal system because of the danger of a direct flow to the shore.

Developments of this type should be provided with a treatment facility that will insure a high degree of purification. Sewage lagoons have been used for such purposes, usually with a treated bottom to remove the seepage danger, and have proved successful. Their ability to function most efficiently during the summer months has been an added advantage.

Highway-Oriented Developments

The federally-sponsored system of Interstate Highways will have a profound effect on many urban areas. These highways will allow each community only a few access points, which many times will be located in open country. However, the volume of traffic that can be expected at each access point is likely to attract commercial developments. The commercial developments, usually consisting of gas stations, refreshment stands, restaurants, motels, and similar services, will require sewerage service, but the extension of the municipal system might prove financially unsound.

Highway service centers, located in open country, will almost certainly be tightly grouped around the access point, making them ideal for a community-type sewerage system. As an interim or permanent treatment plant, the lagoon may be the cheapest and most practical method of waste disposal. A similar application of the lagoon may be made to existing highway-service areas removed from city services.

Community-Type Developments

There are many developments that usually locate in areas away from urban concentrations, yet retain a community-type atmosphere. Some of these developments are: summer camps, trailer parks, small military installations, rural schools, and communities related to resource-based industries such as mining camps and petroleum-pumping stations.

A few of these developments will receive their greatest use during the summer months. For these developments the sewage lagoon is particularly well suited. To install a conventional treatment plant would not be economically justified since it would have only seasonal use. The lagoon, however, performs best during the warm summer months and can be easily deactivated without personnel or operational problems. It also has the advantage of being an inexpensive facility, thereby lessening the financial loss suffered through periodic disuse.

For installations that have a yearly need for sewage treatment, the lagoon again has application. Isolated developments are likely to have an abundant supply of idle land nearby. A small portion of this land could be used for a lagoon to act as a central-treatment facility. The low initial cost of a lagoon and its inexpensive operation can provide complete treatment for these types of developments at a substantial savings.

The sewage lagoon can be applied extensively. It has applicability in metropolitan areas and also in isolated developments. It is a practical method of sewage treatment that should receive equal consideration whenever a need for a sewage-treatment facility arises.

The Planning Commission should insure that the placement of permanent lagoons and the reuse potential of interim lagoons correspond with the land development plans for the area. A permanent lagoon should fit into the open-space plan. If additional land is needed for park development it should be acquired with the lagoon site. The interim lagoon site should be considered in the light of proper location and sufficient land area for future park of school use; or, in the case of residential reuse, that an adequate tract of land is available for residential subdivision. These considerations will allow the lagoon site to become an integral part of the total community development plan.

CHAPTER VI

SUMMARY

Providing sewage treatment is a problem that confronts cities of all sizes. Some isolated developments are also confronted with a problem of sewage disposal. In the small community it is usually a problem of securing an inexpensive, yet efficient method of sewage treatment that will not require highly trained operators. In the larger cities, the problem is expanding the sewerage system to accommodate new growth, a task that is difficult to accomplish with conventional facilities alone. An inexpensive interim facility is desired by these larger cities to service the areas of growth until the metropolitan system can be expanded.

The sewage lagoon.--The sewage lagoon is a relatively new method of sewage treatment that is capable of solving the sewerage problems of both small communities and metropolitan areas. Widespread interest has been demonstrated in the lagoon since the first facility was constructed in 1949. Since that time the number of sewage lagoons has rapidly increased until approximately 1,000 lagoons are now in operation in the United States.

The lagoon operates through biological, physical, and chemical processes in a manner often referred to as natural self-purification. The purification process of sewage lagoons and the natural self-purification of streams correspond in the following basic steps: (1) wastes are diluted in a large water body; (2) solids are allowed to settle to the bottom; and, (3) aerobic and anaerobic bacteria purify the wastes without mechanical or chemical aids. The means of obtaining oxygen to support the aerobic bacteria is the only major point where the treatment processes differ. The sewage-lagoon process receives its oxygen from algae, a form of plant life that liberates through photosynthesis more oxygen per given volume of water than streams are able to obtain from the air.

The structure of a sewage lagoon is exceptionally simple in comparison with other treatment devices. A large level area is surrounded with highly compacted earthen dikes to form a basin which holds the lagoon's liquid contents. Inlet and outlet structures are constructed to allow for the input of raw sewage and the output of treated liquid. As a safety measure, the entire structure is surrounded with a fence to exclude animals and people.

Characteristics of lagoons.--Due to the elementary construction of a lagoon, the installation costs are substantially less than most competitive sewage-treatment facilities. The operational costs are also less because the operation of a lagoon is essentially self-sufficient and skilled personnel are not required.

The low cost of lagoons and their ability to provide complete treatment make them adaptable to various sewage-treatment needs. These two factors, low cost and complete treatment, account for the increased use of lagoons by small communities. Lagoons can also be used as an interim treatment device to provide efficient service without incurring a financial loss in unamortized equipment. As a secondary-treatment facility, the lagoon can supplement a primary-treatment plant when an effluent of high quality is desired.

The use of a sewage lagoon is limited primarily by its large land requirement and its inability to function in porous soils. In urban areas a site that is level, has proper soil conditions, and is large enough to accommodate a lagoon is often difficult to find near the proposed service area. Although lagoons, located in areas having porous soils, can be treated with a variety of impervious materials to eliminate the problem of sewage seepage, a substantial increase in their total cost results.

The site requirements for a lagoon are generally similar to those for conventional-treatment plants. Specifically, the lagoon should be placed in an open area, be sufficiently buffered from residences, and be near a continuously flowing stream.

The operational procedures for lagoons are concerned with anticipating and correcting those recurring problems that can cause malfunctions and malodorous conditions. A well designed and well constructed lagoon can be expected to function without experiencing many of these problems. However, a knowledge of their causes and of possible solutions is important for those planning a lagoon as well as for those who will operate the facility.

Applications of the lagoon.--The lagoon can be applied in many different situations. Small communities most often use lagoons as the sole treatment device. However, the lagoon can also be used as a staging device to gradually develop the treatment plant until more compact, conventional facilities can be installed. In isolated developments, such as lakeshore resorts, rural schools, highway service centers, and similar developments, lagoons can be used as a low cost central treatment facility for the entire development.

In metropolitan areas lagoons have been used primarily as an interim treatment facility. When functioning in this capacity the sewage lagoon is actually serving as a tool for sewerage system development. Occasionally the lagoon has served as a permanent treatment device to service those areas that are separated from the metropolitan system by physical barriers. Because of these factors many cities have realized the potential of the sewage lagoon as a development tool and are using it through well conceived programs to aid the development of the metropolitan sewerage system.

Particular attention should be given the reuse potential of interim lagoon sites and the development potential of permanent lagoons. These sites can be used as park and school sites in the suburban areas of large cities or as an integral part of an open-space plan. The Planning Commission, serving in its coordinating capacity, can obtain substantial savings for the municipality through the intelligent placement of the lagoon.

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